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A TELECOMMUNICATIONS METHOD

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(71) Applicant(s)
TELSTRA CORPORATION LIMITED

(72) Inventor(s)
MOSHE ZUKERMAN

(74) Attorney or Agent
DAVIES COLLISON CAVE, 1 Little Collins Street, MELBOURNE VIC 3000

(57)

A telecommunications method including transmitting calls on frames divided into a plurality of time slots, full rate calls being allocated to respective ones of the slots and up to two half rate calls being allocated to respective ones of the slots, reallocating the calls to the slots when one of the calls is completed if two half rate calls allocated to two of the slots can be allocated to one of the slots, reserving a last slot of the frames for full rate calls, and allocating a percentage of half rate calls to the last slot.

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COMPLETE SPECIFICATION
FOR A STANDARD PATENT
(ORIGINAL)

Name of Applicant: **TELSTRA CORPORATION LIMITED**, A.C.N. 051 775 556, of 242 Exhibition Street, Melbourne, Victoria 3000, Australia

Actual Inventor: Moshe ZUKERMAN

Address for Service: **DAVIES COLLISON CAVE**, Patent Attorneys, of 1 Little Collins Street, Melbourne, Victoria 3000, Australia

Invention Title: **A TELECOMMUNICATIONS METHOD**

Details of Associated Provisional Application No: PN1499/95

The following statement is a full description of this invention, including the best method of performing it known to us:

A TELECOMMUNICATIONS METHOD

The present invention relates to a telecommunications method and, in particular, to a method for allocating calls to time slots.

Time division multiple access (TDMA) frames can be used to transmit calls, the frames being divided into time slots and calls being allocated to a respective slot in a frame. The data for a call is therefore distributed over a number of slots of different frames. The GSM mobile telecommunications system uses TDMA frames to transmit calls between base stations and mobile stations in a cellular network. Full rate calls are allocated entire slots of consecutive TDMA frames. Half rate speech codecs have become available which can rely on slots of every second frame. The traffic handled by a base station can now be a mix of half and full rate traffic. To fully utilise the capacity of a base station, calls need to be judiciously allocated slots in a TDMA frame according to a slot allocation method. The allocation method should take into account the slots made available when calls are completed and how calls can be reallocated to maximise the traffic which a base station can accept.

In addition to the frames being used as efficiently as possible, consideration also needs to be given to ensuring that full rate customers are not compromised by the introduction of half rate customers, bearing in mind half rate calls occupying a slot will not preclude another half rate call being allocated to that slot, but will preclude a full rate call being allocated. The allocation scheme should provide fairness by ensuring that the probability of a full rate call being not allocated a slot, or blocked, is not significantly different than the probability of a half rate call being blocked.

In accordance with the present invention there is provided a telecommunications method including:

transmitting calls on frames divided into a plurality of time slots, full rate calls being allocated to respective ones of said slots and up to two half rate calls being allocated to respective ones of said slots;

reallocating said calls to said slots when one of said calls is completed if two half rate calls allocated to two of said slots can be allocated to one of said slots;

reserving a last slot of said frames for full rate calls; and

allocating a percentage of half rate calls to said last slot.

Preferably said percentage includes a first percentage of half rate calls allocated to said last slot when said last slot is empty, and a second percentage of half rate calls allocated when said last slot has been allocated one half rate call. The first percentage may be 60% and the second percentage 100%.

Advantageously said percentage may be determined on the basis of the arrival rate of calls for transmission.

The method may include allocating a half rate call to said last slot with a probability p_1 which is a function of the arrival rate of full rate calls λ_1 and half rate calls λ_2.

The method may also include allocating a further half rate call to said last slot with a probability of p_2 after a first half rate call has been allocated to said last slot, said probability p_2 being a function of λ_1 and λ_2 and N_h where N_h is the number of half rate calls which have been allocated slots. For eight slot TDMA frames, p_1 may be 0.6 and p_2 may be 1.0.

A preferred embodiment of the present invention is hereinafter described, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a diagram of full rate speech frames being assigned to time slots;

Figure 2 is a diagram of half rate speech frames being assigned to time slots;

Figure 3 is a diagram of mixed traffic calls allocated to TDMA frames;

Figure 4 is a diagram of a TDMA frame model for mixed traffic;

Figures 5 to 9 are graphs illustrating blocking performance for different allocation methods;

Figure 10 is a graph illustrating blocking performance for a preferred embodiment of an allocation method; and

Figure 11 is a graph of full/half rate blocking ratios for the different allocation method and the preferred embodiment of an allocation method.

The GSM system employs speech encoding methods which are intended to minimise the amount of information transmitted and the bandwidth required because the system uses the radio frequency band which is a limited resource. Pulse code modulation (PCM) encoding needs 64 kbit/s to be transmitted, whereas the data rate required for a full rate GSM speech codec is only 13 kbit/s, and in a half rate codec the data rate is 6.5 kbit/s. For a full rate speech channel or call, 8000 speech samples are grouped into 20 msec speech frames of 160 samples each. After analog-to-digital conversion these 160 speech samples are encoded by 260 bits. Before transmission these 260 bits are error protected, and for this purpose the GSM system uses convolutional encoding. After convolutional encoding, each speech frame 2, as shown in Figure 1, consists of 456 bits.

The GSM system uses a TDMA transmission method, with each channel placed in a separate time slot 4 of a TDMA frame. Each group of 456 bits is distributed over 8 time slots, 57 bits into each. This operation spreads out in time the bits to be transmitted, and improves the error correction performance of a convolutional decoder. Each time slot contains 57 bits from two adjacent speech frames, a total of 114 bits, as shown in Figure 1. Each time slot 4, shown in Figure 1, is a part of 4.615 ms TDMA frame, also containing another 7 time slots occupied by other channels or calls. Thus each speech frame is spread over 8 frames or 37 ms. Figure 1 shows only one user's time slots.

For a half rate speech channel or call each speech frame contains 130 bits, which

after convolutional encoding results in 228 bits. In order to have similar to full rate channel signal processing the bits from two adjacent speech frames are added, so each channel 8 and 10 has, after convolution encoding, speech fames 6 of 456 bits separated by a time interval of one speech fame, as shown in Figure 2. For this signal transmission it is not necessary to use time slots 4 in every time frame, as for full rate channel. A half rate channel 8 only occupies a time slot in every second time frame, leaving the empty time slots 6 for other half rate channels 10, as shown in Figure 2. Each group of 456 bits in a half rate channel, as in a full rate channel, is distributed over 8 time frames, but now only over odd or only over even time frames of 74 ms.

Mobile stations or terminals may have the capability to process calls at both the full rate and half rate. However, if a base station for a cell is equipped with half rate capability the terminals may operate in the half rate mode in that cell. The organisation of slots for full and half rate transmission is in accordance with GSM standards and is described in, Mouly M. and Pautet M., "The GSM System for Mobile Communications". France: Michel Mouly and Marie-Bernadette Pautet, 1992. The GSM frame format, channels used and the components of a base station and mobile terminal are described in the specification of International Patent Application No. PCT/AU94/00561.

Mixing the traffic from the full and half rate sources can conceivably result in 8 full rate calls being served, 16 half rate calls being served, or any feasible combination of these. Figure 3 illustrates a situation where a frame 12 has time slots 1, 4 and 7 used by three different full rate calls 14 and time slots 3, 5 and 8 used by first, second and third half rate calls 16, 18 and 20. In the succeeding frame 22, whilst time slots 1, 4 and 7 continue to be used by the full rate calls 14, time slots 3 and 5 are empty and time slot 8 is being used by a fourth half rate call 24.

Whilst it initially appears that half rate calls will double the capacity of a GSM network, it needs to be borne in mind that not all existing GSM customers will move to the half rate system, particularly as a new mobile terminal handset is required. Furthermore, when a half rate call occupies a time slot, a full rate call cannot be accepted for that time slot and therefore from the point of view of full rate traffic, a half

rate call effectively takes up a complete time slot. When the last available time slot is occupied by a half rate call, a full rate call cannot be accepted and is effectively blocked.

For the purposes of evaluating the traffic performance of a mixed full and half rate network, the slot allocation described above can be represented as slots being allocated either one full rate call or two half rate calls. With reference to the example of Figure 3, the full rate calls 14, as shown in Figure 4, are considered as being allocated to full slots 1, 4 and 7, whereas the first and second half rate calls 16 and 18 are considered to occupy only half of time slots 3 and 5. The third and fourth half rate calls 20 and 24 are considered to fill both halves of time slot 8 because they utilise alternative frames 12 and 22. The boundaries between the eight slots 4 are considered "stone walls", in the sense that a full rate call may never be placed across one of these walls. For simplicity, this model considers a single frame with no broadcast or control channels. For the examples used herein, the performance of different slot allocation methods is examined using the single frame model 30 illustrated in Figure 4. The description of the methods and the performance evaluation can, however, be extended to multiple frames 12 and 22 related to different radio frequency carriers in the same cell.

Slots are allocated or calls allocated to slots during a GSM call set up procedure, as described in the specification of International Patent Application No. PCT/AU94/00561. According to a random slot allocation method, a base station will perform the following as full and half rate calls arrive:

(a) In the case of full rate calls, choose at random one of the free full slots available, being careful to keep within the "stone wall" boundaries.

(b) In the case of half rate calls, choose at random one of the free half slots available.

As each call is completed, this leaves a full or half slot "hole", and there is no action taken by the base station at this point. Hereinafter full slots that only have one half rate occupant will be referred to as "lone half" slots.

According to a first fit allocation method, the eight 4 slots in the frame 30 are permanently allocated ID numbers (say 0-7). Each full slot may contain: (i) no calls [0]; (ii) a half slot [1]; (iii) two half slots [2]; or (iv) a full slot [3]. To each of these possibilities, a numerical value is attached, as has been done in the square brackets.

The allocation procedure of a base station then executes the following:

(a) Each incoming half rate call is allocated to the smallest ID-number full-slot (i.e. imaginary packing from the left hand side of the frame 30), with only 0 or 1 half rate calls currently there.

(b) Each incoming full rate call is allocated to the smallest ID-number full-slot that is totally empty.

Similarly to the random allocation method, as each call leaves, it leaves a full or half slot hole, and there is no allocation action taken by the base station on call completion.

A best fit allocation method is more efficient than either of the two previous methods, because it specifically targets the lone half slots that are present in the frame, and eliminates these by adding to them any new incoming half rate calls. Frames are more closely packed, providing more room for full rate calls. Specifically, the method is as follows:

(a) Incoming full rate calls are packed from the left of the frame 30, exactly as described for the first fit allocation method, as calls are allocated to the smallest ID numbered slot which is currently empty.

(b) The priority for incoming half rate calls is that they be allocated to a lone half slot, in order to effect maximum compression. If more than one is available, the one with the smallest ID number is filled. On the other hand, if none are available, the call is allocated the smallest ID numbered empty slot which is empty.

Once again, no allocation action is taken upon call departure, and a hole remains behind.

A repacking allocation method is one of the most efficient methods of slot allocation, and is almost identical to the best fit allocation method, except upon call completion or departure, the following occurs

(a) When a full rate call departs leaving a full slot hole, no action is taken.

(b) When a half rate call departs, either a full hole or half hole will remain. In the former case, no action is taken. In the latter case, if a lone half slot is being used, it is moved into the half hole. If not, no action is taken.

Implementation of the repacking strategy can make use of intracell hand over procedures including repacking across different radio frequency carriers within the same cell.

The repacking method ensures there is no more than one isolated half slot, and increases utilisation. The only essential difference between admittance criteria for full and half rate calls is that when there are 7½ slots full, a half rate call will be admitted, whereas a full rate call will not.

The repacking method can be altered by introducing a small amount of resource wastage, whereby half rate calls are prevented from being admitted by the base station when 7½ slots have already been allocated. The system will then behave similarly for both full rate and half rate traffic, at the expense of lowering the half rate call utilisation. This modified allocation method can be referred to as repacking with perpetual half slot reservation (RPHSR).

A further method is repacking with perpetual reservation (RPR). This method is the same as the repacking method except a full slot is always reserved for use only by full rate calls. This is not necessarily always the same slot but can be considered as being the last slot to be allocated. The admission of full rate calls will remain the same, whereas the admission of half rate calls is impeded, in the sense that half rate calls are only able to use 7 of the 8 slots of the frame 30. The method has the advantage that

it will equalise the blocking of full rate calls with that of half rate calls, as the blocking probabilities for half rate calls is far smaller than that for full rate calls, using the repacking method.

The preferred embodiment of the present invention, described hereinafter, can be referred to as a repacking with random reservation (RRR) method. The RRR method is a further variation of the repacking method where a slot is reserved for full rate calls however the reserved last slot may be used by half rate calls under selected operating conditions.

According to the RRR method, if 7 slots are filled, one full slot is empty and a half rate call arrives, then with probability p_1, the call is accepted, and with probability $(1-p_1)$ the call is rejected. If 7 slots are filled, and the reserved slot already contains a lone half slot, then with probability p_2, the call is accepted, and with probability $(1-p_2)$ the call is rejected.

The probability p_1 is set as a function of the arrival rates λ_1 and λ_2 for the two types of traffic, such that $p_1 = f(\lambda_1,\lambda_2)$. For example, if the number of full rate arrivals is of an order of 10 or 100 smaller than half rate arrivals, a high value of p_1 is specified by the function. The method allocates a half rate call to the reserved slot depending on the arrival rates λ_1 and λ_2.

The probability p_2, on the other hand is associated with the event of already having admitted a half rate call into the reserved slot, and is a function of not only the arrival rates, but also of the current number N_h of half rate calls currently allocated slots. That is $p_2 = f(\lambda_1,\lambda_2,N_h)$. For example, if many half rate calls have been allocated slots (large N_h) and a half rate call attempts to use the reserved slot, it may be rejected because:

(i) With a high number of half rate calls currently allocated, there is an increased probability that a half rate call will be completed, and therefore the current half rate call successfully admitted when a further attempt is made for admission.

(ii) Half rate calls appear to be dominating the system and in order to equalise the service of both half and full rate customers, it is advisable to wait until the lone half slot in the reserved slot departs thereby providing capacity for full rate customers.

A base station may execute the RRR method by reserving the last slot and allocating half rate calls to that slot on the basis of p_1 and p_2 by using a random number generator to generate a result which determines whether a half rate call is to be accepted or rejected. For example, if p_1 is set to be 0.6 and the random number generator is configured to generate numbers between 0 and 1, if on attempted admission of a half rate call to the last slot, the random number generator produces a number equal to and less than 0.6, that half rate call will be accepted, otherwise for any higher number the call is rejected or blocked. The same procedure can be executed to determine admission of half rate calls to the last slot when another half rate call has already been allocated to the slot, this time using a value determined for p_2. To simplify the procedure, p_2 can be set equal to 1 so that all half rate calls are admitted to the last slot once a half rate call has already been allocated. This enhances utilisation of the last slot, as once a half rate call has been allocated to it, a full rate call cannot use the slot, but another half rate call can be allocated to the slot.

Blocking probabilities have been measured against a percentage of full rate traffic for each of the allocation methods and the results are illustrated in Figures 5 to 10. The blocking probabilities have been determined using a Markov chain event simulation where a certain utilisation of frames is chosen and a large number of full and half rate call events are either admitted or rejected from the frames on the basis of the allocation methods. The probability that a call is blocked can then be determined from the results of the simulation for different levels of full and half rate traffic. For example, if the percentage of full rate traffic is 80% then the percentage of half rate traffic is 20%. The Figures display the full and half rate blocking probabilities at both the 40% and 70% levels of utilisation. Utilisation is defined as the average number of occupied slots and, for a system where blocking probability is negligible, is given by:

$$p = \frac{\lambda_1 + \frac{1}{2}\lambda_2}{8\mu}$$

The numerator represents the total demand on a base station in unit time, where λ_1 is the arrival rate of full rate calls and λ_2 is the arrival rate of half rate calls which according to the frame model 30 only occupy half a slot. In the denominator, 8 represents the number of slots in a frame and μ is the inverse of the call duration or holding time and is assumed to be the same for both full and half rate calls. The percentage of full rate traffic P_F and half rate traffic P_H are given by:

$$P_F = \frac{\lambda_1}{\lambda_1 + \lambda_2}$$

and

$$P_H = \frac{\lambda_2}{\lambda_1 + \lambda_2}$$

A slot allocation method for a base station can be varied by making appropriate adjustments to the existing software and/or hardware of the base station.

Figure 9 provides an insight into the ratio of full rate blocking to half rate blocking, at the two utilisations. Figure 11 illustrates the ratio of full rate to half rate blocking probabilities for the two utilisations for each of the allocation methods.

The Figures illustrate that full rate customers will suffer relatively high blocking probabilities compared to half rate customers, unless an efficient and fair slot allocation method is employed. The RRR method of the preferred embodiment is the most efficient and fair slot allocation method as it is able to keep the blocking probabilities almost identical for both full rate and half rate customers for most traffic mixes. If the arrival rates λ_1 and λ_2 are unknown, it has been found that by setting $p_1 = 0.6$ and $p_2 = 1$, will give approximately equal blocking probabilities for both half and full rate calls.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A telecommunications method including:

transmitting calls on frames divided into a plurality of time slots, full rate calls being allocated to respective ones of said slots and up to two half rate calls being allocated to respective ones of said slots;

reallocating said calls to said slots when one of said calls is completed if two half rate calls allocated to two of said slots can be allocated to one of said slots;

reserving a last slot of said frames for full rate calls; and

allocating a percentage of half rate calls to said last slot.

2. A telecommunications method as claimed in claim 1, wherein said percentage includes a first percentage of half rate calls allocated to said last slot when said last slot is empty, and a second percentage of half rate calls allocated when said last slot has been allocated one half rate call.

3. A telecommunications method as claimed in claim 2, wherein the first percentage is 60%.

4. A telecommunications method as claimed in claim 2 or 3, wherein the second percentage is 100%.

5. A telecommunications method as claimed in claim 1 or 2, wherein said percentage is determined on the basis of the arrival rate of calls for transmission.

6. A telecommunications method as claimed in claim 1 or 2, including allocating a half rate call to said last slot with a probability p_1 when said last slot is empty.

7. A telecommunications method as claimed in claim 6, including allocating a further half rate call to said last slot with a probability of p_2 after a first half rate call has been allocated to said last slot.

8. A telecommunications method as claimed in claim 6 or 7, wherein said probability p_2 is a function of the arrival rate of full rate calls λ_1 and half rate calls λ_2.

9. A telecommunications method as claimed in claim 8 when dependent on claim 7, wherein said probability p_2 is a function of λ_1 and λ_2 and N_h where N_h is the number of half rate calls which have been allocated slots.

10. A telecommunications method as claimed in any one of claims 6 to 9, wherein said probability has a value within a range of values, and said method includes generating a random value with said range and accepting a half rate call if said random value is less than or equal to said value.

11. A telecommunications method as claimed in claim 10, wherein said range is 0 to 1.

12. A telecommunications method as claimed in claim 6, 7 or 11, wherein p_1 is 0.6.

13. A telecommunications method as claimed in claim 7 or claims 11 or 12 when dependent on claim 7, wherein p_2 is 1.

14. A telecommunications method substantially as hereinbefore described with reference to the accompanying drawings.

15. The steps, features, compositions and compounds disclosed herein or referred to or indicated in the specification and/or claims of this application, individually or collectively, and any and all combinations of any two or more of said steps or features.

DATED this 4th day of March, 1996
TELSTRA CORPORATION LIMITED
By its Patent Attorneys
DAVIES COLLISON CAVE

ABSTRACT:

A telecommunications method including transmitting calls on frames divided into a plurality of time slots, full rate calls being allocated to respective ones of the slots and up to two half rate calls being allocated to respective ones of the slots, reallocating the calls to the slots when one of the calls is completed if two half rate calls allocated to two of the slots can be allocated to one of the slots, reserving a last slot of the frames for full rate calls, and allocating a percentage of half rate calls to the last slot.

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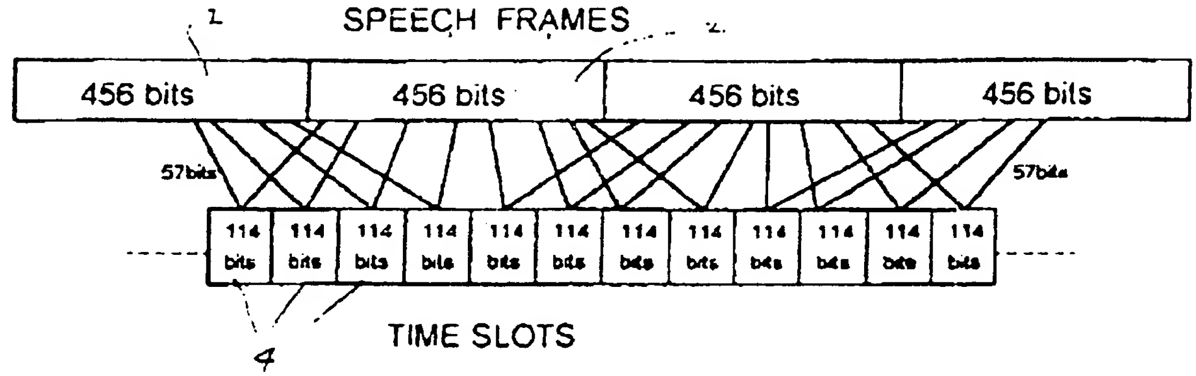

Figure 1

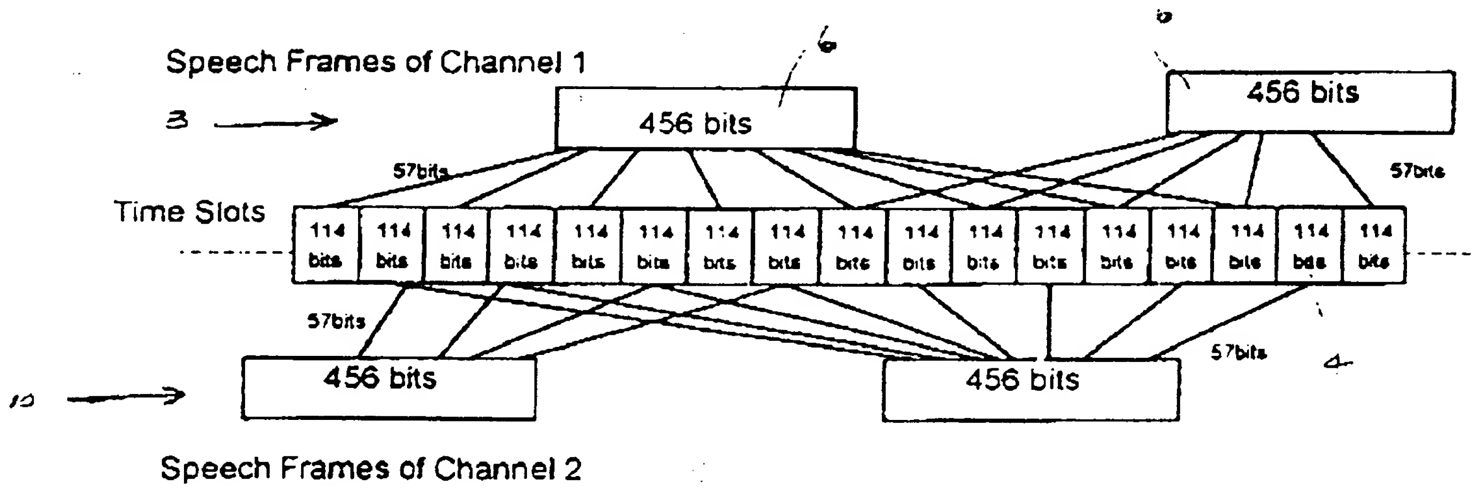

Figure 2

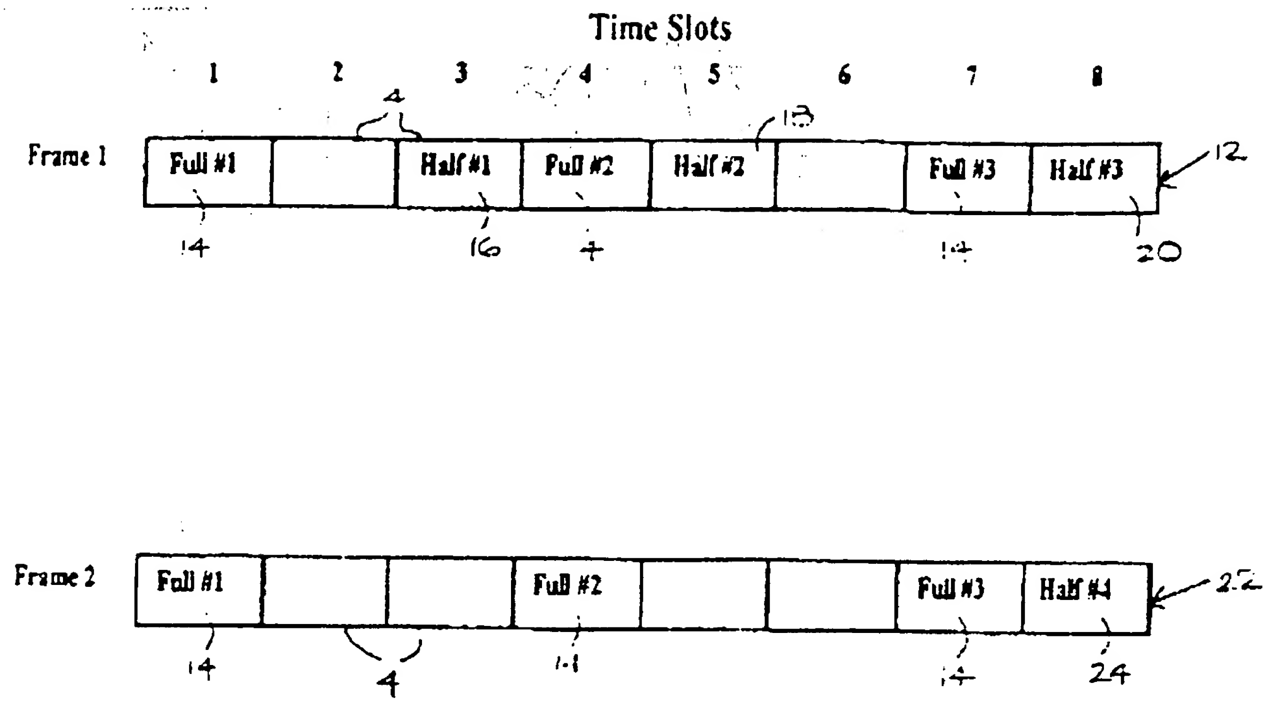

Figure 3

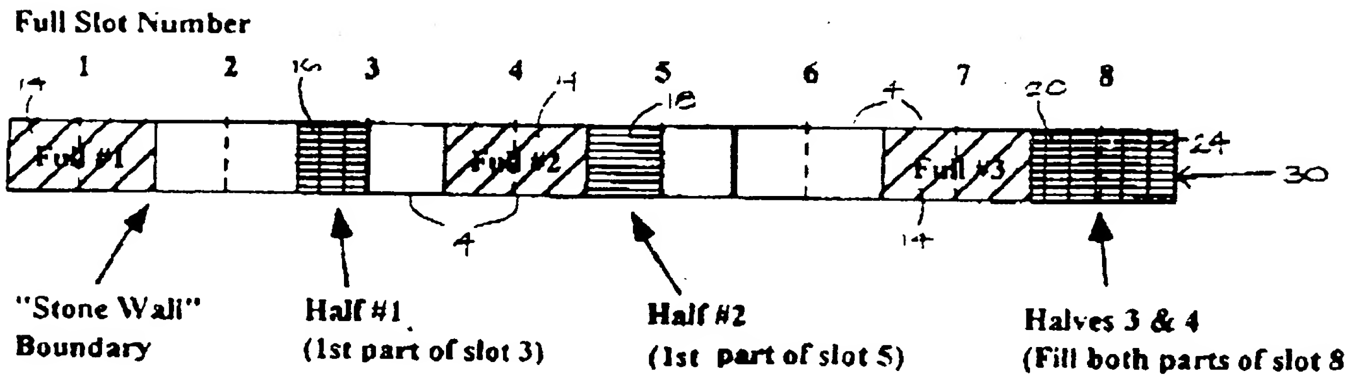

Figure 4

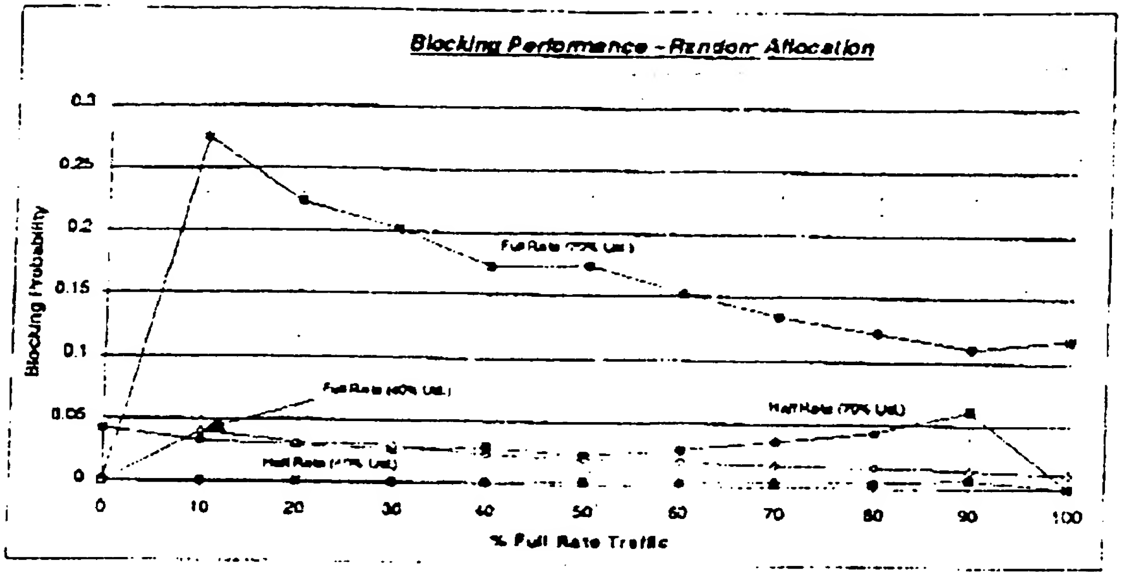

FIGURE 5

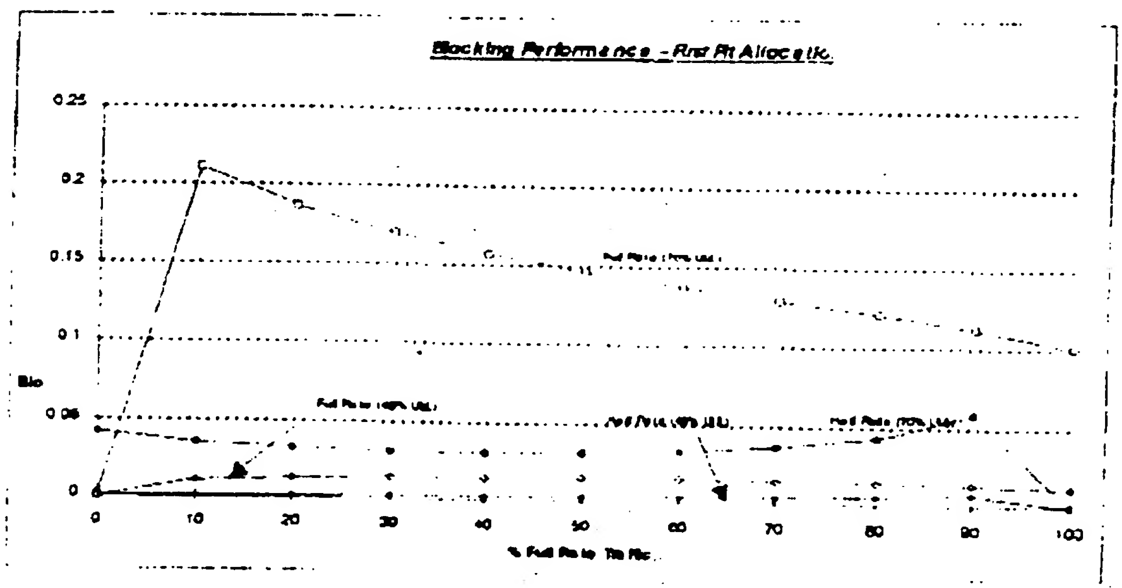

FIGURE 6

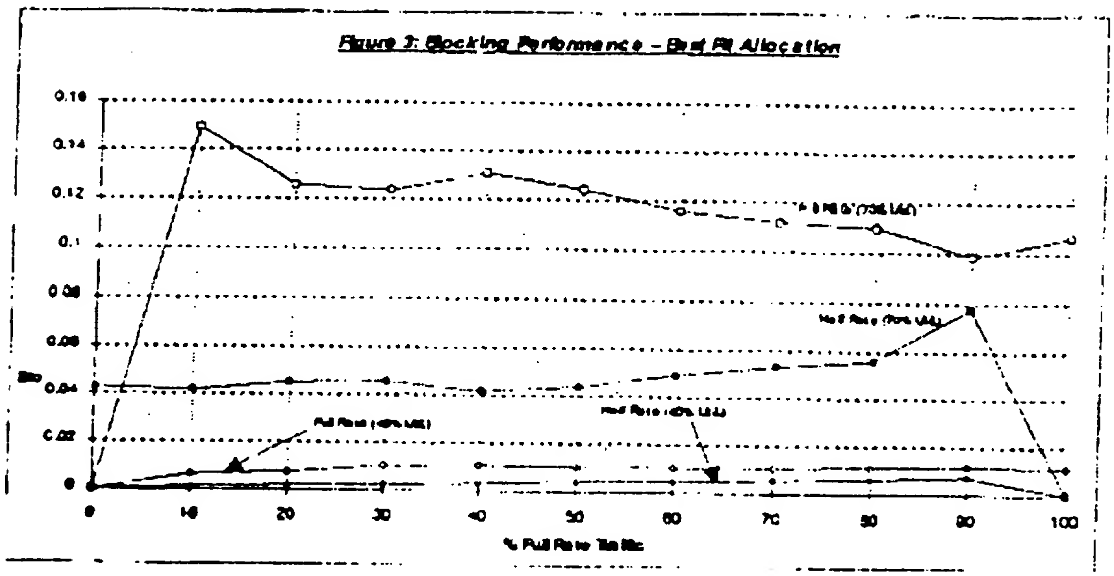

FIGURE 7

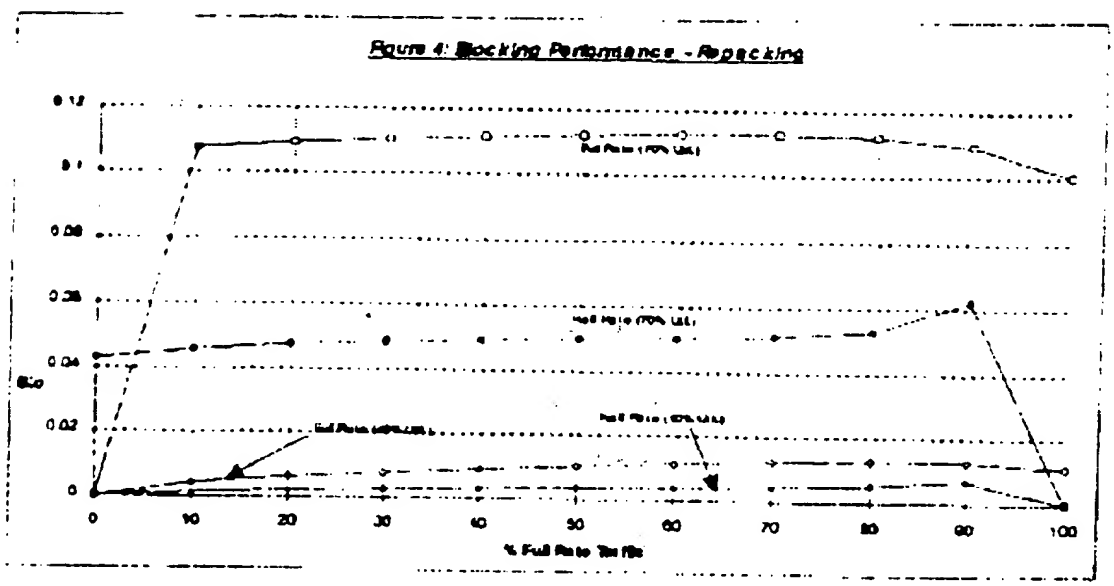

FIGURE 8

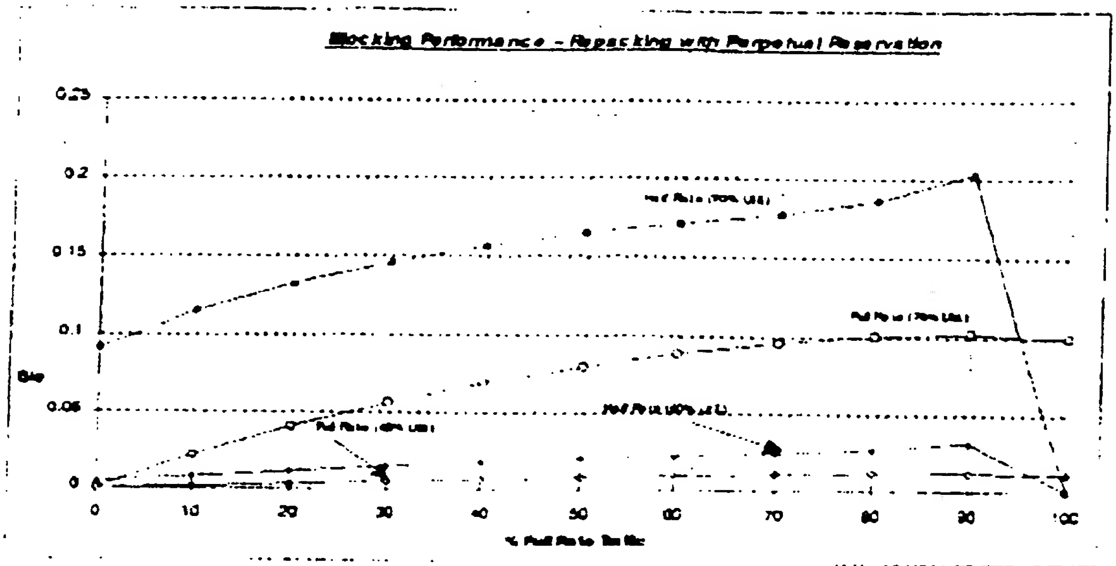

FIGURE 9

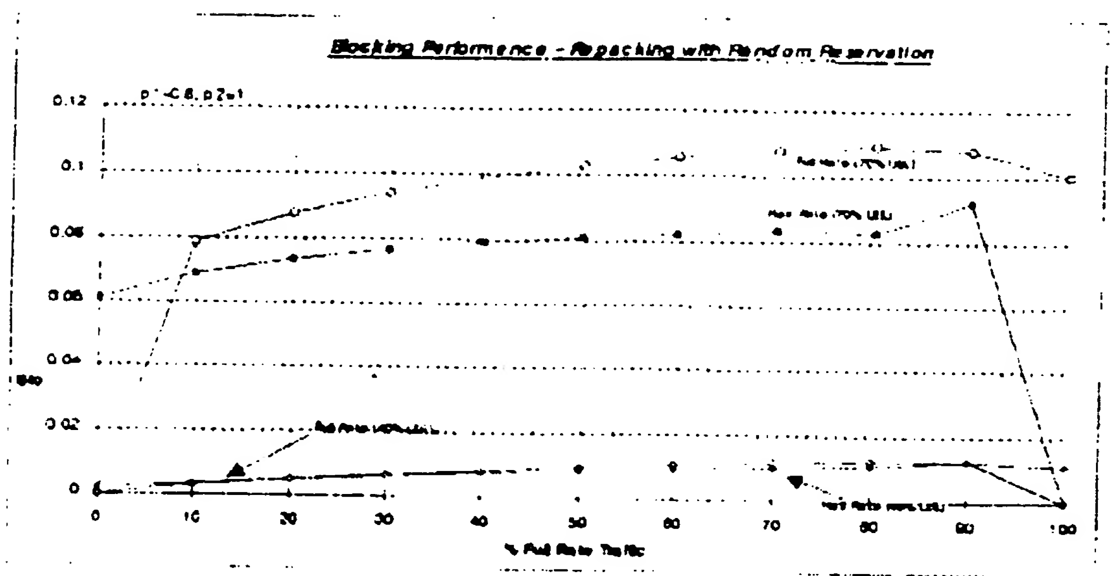

FIGURE 10

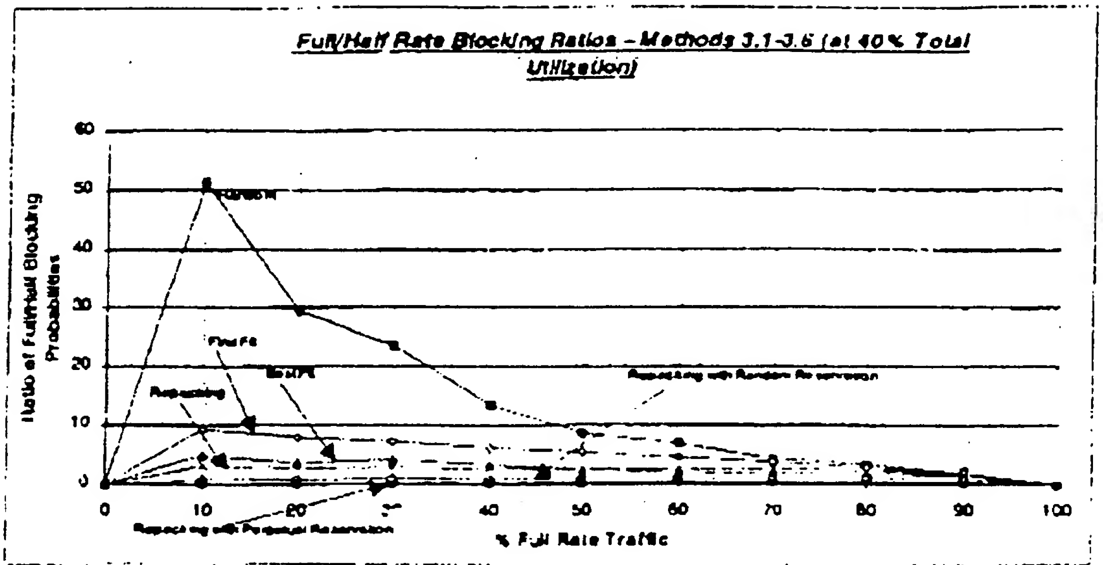
Full/Half Rate Blocking Ratios - Methods 3.1-3.6 (at 40% Total Utilization)
Ratio of Full/Half Blocking Probabilities
0
10
20
30
40
50
60
First Fit
Best Fit
Repacking
Repacking with Random Reservation
Repacking with Perpetual Reservation
0
10
20
40
50
60
70
80
90
100
% Full Rate Traffic

FIGURE 11

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